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(56) Documents Cited

GB 2358202 A

GB 2324108 A

US 6056054 A

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(54) Abstract Title

Downhole pump driven by injection water

(57) A method of enhancing hydrocarbon production involves pumping injection water down a wellbore to drive a downhole pump assembly (13) and using the pump assembly (13) to increase the production rate of hydrocarbons from the well. The injection water, after driving the pump assembly (13), exits through outlets (25) below a packer (17) and enters the injection zone (19) thereby driving hydrocarbons into the pump assembly (13) initially through inlets (10). The pump assembly (13) includes a turbine unit (12) driven by the movement of the injection water over turbine blades (32, fig 2).

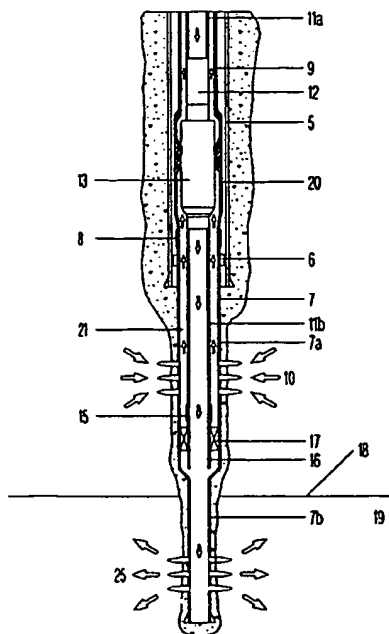
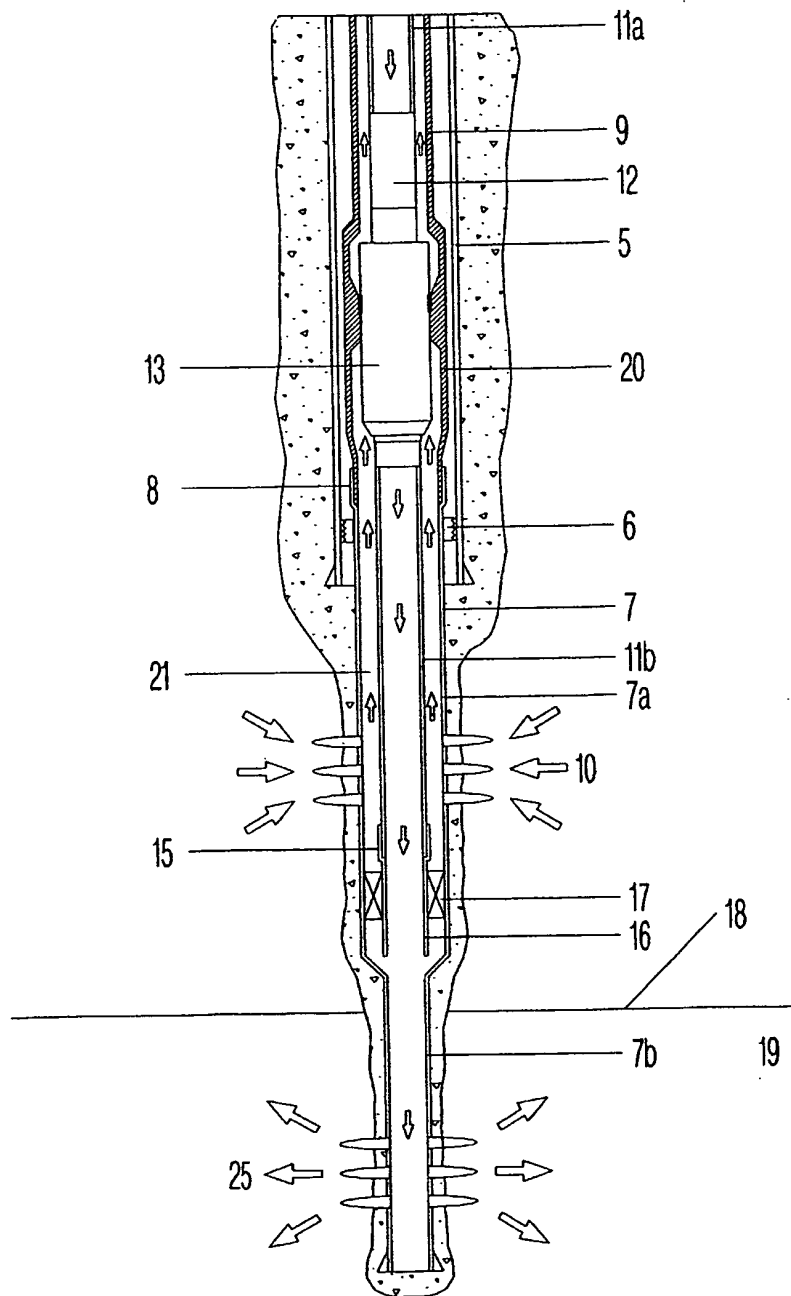


Fig. 1

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**Fig. 1**

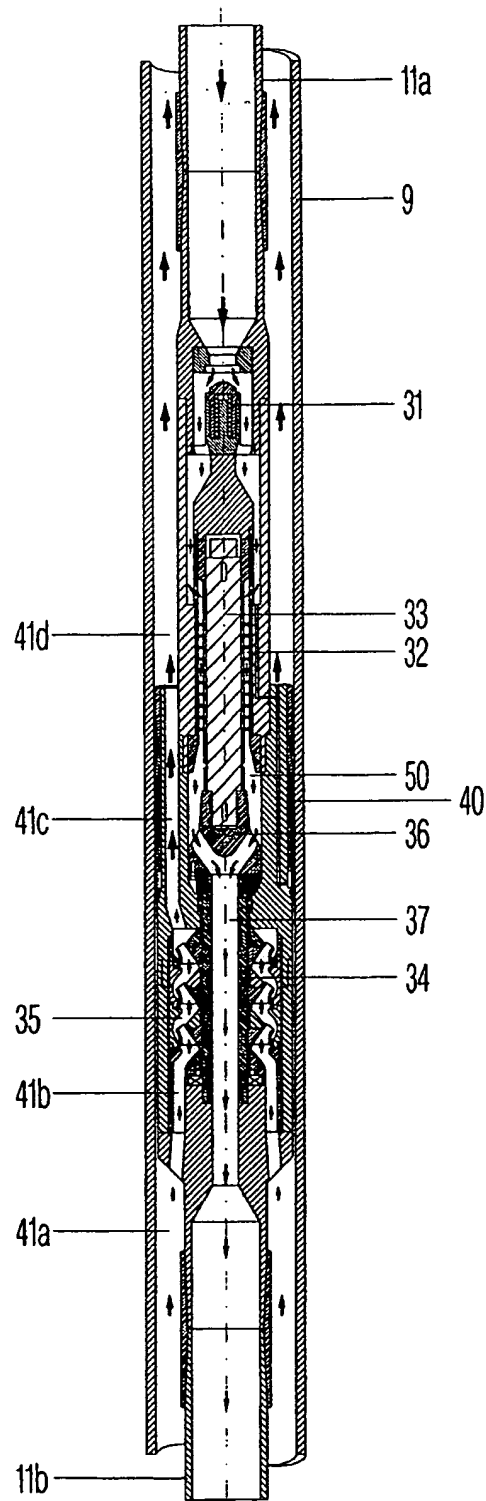


Fig. 2

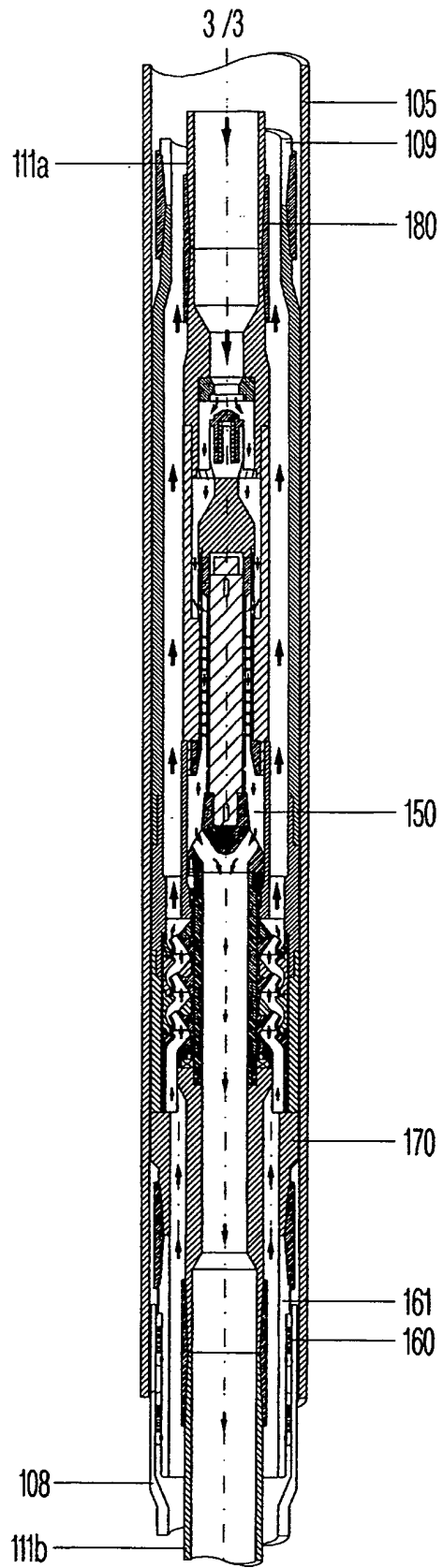


Fig. 3

1 **"DOWNHOLE PUMP"**

2

3 The present invention relates to a pump, and
4 particularly one to be installed downhole for
5 recovery of hydrocarbon fluids from drilled wells,
6 and for the injection of fluids such as water into
7 such wells in order to stimulate the production of
8 fluid hydrocarbons therefrom.

9

10 Oilfield reservoirs generally consist of a layer of
11 hydrocarbon fluids such as oil which lies on top of
12 a denser layer of water called the aquifer. In low
13 pressure wells or wells which have been produced for
14 a number of years and which no longer have
15 sufficient natural pressure to allow unaided flow of
16 hydrocarbons from the reservoir payzone to surface,
17 it is conventionally known to inject water into the
18 underlying aquifer in order to maintain or increase
19 the pressure in the reservoir and to enhance the
20 flow of hydrocarbon fluids into a wellbore.

21

22 According to the present invention there is provided
23 a pump for drawing a first fluid from a first end of
24 the pump to a second end, the pump being powered by
25 the flow of a drive fluid from the second end to the
26 first, wherein the first fluid and the drive fluid
27 flow through separate conduits, one of the conduits
28 being located within the other.

29

1 The said one conduit is preferably entirely
2 contained within the said other conduit.

3
4 In the pump of the invention, the drive fluid
5 preferably goes through a first conduit, and the
6 produced first fluid goes through the other in the
7 opposite direction. The pump of the invention
8 therefore avoids crossover of drive and produced
9 fluids in the body of the pump. Certain embodiments
10 can also minimise the complexity of downhole
11 completion.

12
13 In a preferred embodiment of the invention, the
14 drive fluid passes down an inner conduit, and the
15 produced fluid passes up the annulus between the
16 inner conduit and an outer tube. The blades of a
17 turbine are preferably disposed in the path of the
18 inner conduit and the turbine preferably provides
19 power to a shaft which powers a pump driving the
20 produced fluids up through the outer annulus.
21 However, the drive fluid could equally pass through
22 the outer annulus, and the production fluid could
23 pass through the inner conduit. The pump in the
24 outer annulus can be a centrifugal pump.

25
26 An embodiment of the invention will now be described
27 by way of example and with reference to the
28 accompanying drawings in which;

29 Fig. 1 shows a schematic diagram of a pump of
30 the present invention;

31 Fig. 2 shows a sectional view of a pump of
32 another embodiment;

1 Fig. 3 shows a sectional view of a third
2 embodiment of a pump according to the
3 invention.

4

5 Referring now to the drawings, the well schematic
6 shown in Fig. 1 comprises a borehole lined with
7 casing 5 which is cemented in place in the borehole
8 in a conventional manner. A tapered liner 7, of
9 which 7a and 7b are the upper and lower sections, is
10 hung off from casing 5 by a liner hanger 6, is
11 cemented in situ and perforated at 10 in a reservoir
12 payzone allowing ingress of hydrocarbon fluids, and
13 is additionally perforated at its furthest extremity
14 25 to allow injection of water or other liqueous
15 fluids into an aquifer 19. The liner 7 terminates
16 at its upper end in a polished bore receptacle 8, in
17 which is received the lower end of a tieback tubing
18 string 9 which includes a dedicated sealing/locking
19 element 20, known in the industry as a nipple. The
20 liner 7, nipple 20 and tieback tubing 9 provide an
21 outer string in which is disposed tubing 11a, a
22 turbine sub 12, a pump body 13 located in the nipple
23 20 and injection tubing 11b which is received in the
24 polished-bore receptacle 15 of a packer shoe 16
25 sealed by packer 17 to the cemented liner at the
26 lower end of section 7a between the perforations 10
27 and 25. Use of PBRs facilitates installation and
28 retrieval of injection tubing for maintenance etc.

29

30 The bore of the turbine sub 12, pump body 13, the
31 injection string of 11a and 11b, packer shoe 16 and
32 section 7b of liner 7 provide an inner injection

1 conduit located within the outer annular conduit.
2 The outer wall of the outer flow conduit comprises
3 the upper section 7a of liner 7, the outer wall of
4 the pump body 13 sealed against nipple 20 and
5 tieback tubing 9. The inner injection string is
6 located wholly within the bore of the outer string,
7 and is provided for the injection of aqueous fluid
8 such as water to the perforations 12 located in the
9 aquifer 19 below the oil/water interface 18 and
10 horizontally distant from the production
11 perforations 10 so as to reduce the propensity to
12 coning. The outlet of the inner injection string is
13 located below the packers 17 thus preventing leakage
14 of water from the injection string back up the
15 annulus.
16
17 The outer wall of the annular conduit comprising the
18 cemented liner 7 and tieback tubing 9 including
19 nipple 20 directs produced fluids entering the
20 annulus 21 through perforations 10 up said annulus
21 21, through the pump body 13 and thence to surface.
22 Injection of water through the inner injection
23 string and lower perforations 25 below the oil water
24 interface 18 maintains the pressure of hydrocarbon
25 fluids entering the outer recovery string through
26 upper perforations 10 where the reservoir and
27 aquifer are in contact, and maximises recovery of
28 produced fluids from the outer annulus.
29
30 In the embodiment shown in Fig. 2, the bore of a
31 tieback tubing string 9 houses a single inner string
32 of tubulars 11a and 11b for injection of fluids and

1 the annulus is provided between the inner string and
2 the tieback tubing string 9. It is noted that there
3 is no nipple in the tieback tubing string 9.

4
5 Tubing 11a is attached to the pump assembly in which
6 is established a check valve sub-assembly 31.
7 Opening of the check valve 31 allows flow of
8 injected fluid through to a turbine assembly in
9 which the flow of fluid is directed into the path of
10 a number of turbine blade stages 32. Flow of fluid
11 across the blades 32 causes rotation of the solid
12 shaft 33, which drives a pump shaft 34 on which are
13 mounted impeller stages 35. The respective shafts
14 are mechanically connected by flow coupling 36, said
15 flow coupling also providing passage for fluids
16 leaving the turbine stage through to the pump shaft
17 34 which is hollow. The flow coupling is an
18 important preferred feature of the invention as it
19 can simultaneously entrain the pump shaft 34 from
20 the turbine shaft 33, and ensures continuity of flow
21 from the turbine exhaust chamber 50 through the bore
22 37 of pump shaft 34. The flow holes through the
23 flow coupling would preferably be shaped in the
24 manner of an impeller. Fluids leaving the turbine
25 blades 32 are directed into the bore 37 of the pump
26 shaft 34, said bore being in flow connection with
27 the lower tubing string 11b leading to a lower
28 injection point into the aquifer(see Fig. 1).

29
30 The tieback string 9 is preferably landed in the
31 Xmas tree by a hanger at its upper extremity, and is
32 set in the polished bore receptacle of a tapered

1 liner at its lower extremity. A practical
2 alternative to the polished bore receptacle is use
3 of a packer. It is to the bore of string 9 that the
4 pump assembly preferably seals. The method of Fig.
5 1 uses an external seal, typically in the form of
6 chevron packing, set in a dedicated receptacle of a
7 nipple type readily available to the industry. The
8 preferred embodiment of Fig. 2 is of a pressure-
9 activated external packer and slip system made
10 integral with, or attached to, the pump assembly.
11 The pump assembly is shown locked and sealed to the
12 tieback string 9 by a slips/seal packer. The pump
13 provides an annular flow path for produced fluids in
14 complete isolation from the injection fluids.
15 Produced fluids passing up the production annulus
16 41a enter the pump at 41b, are directed into the
17 pump impellers 35 and flow thence to surface through
18 pump exit 41c and upper annulus 41d.
19
20 The slips/seal packer assembly 40 is a standard item
21 in the industry and may be set mechanically or
22 hydraulically. The advantage in providing a packer
23 40 is that the pump can be set at any desired depth
24 within in the tieback tubing string 9. The
25 embodiment of Fig. 2 allows the drive fluid pressure
26 to be used to set the packer 40 although 'hot
27 lines'- small bore tubing - may be run to the packer
28 from surface to provide setting and unsetting
29 pressures.
30
31

1 The modified embodiment of the invention as shown in
2 Fig. 3 has many similar components and will be
3 referred to for ease of reference using the same
4 numbering system but with 100 added where required
5 by context. Inside the body of the pump, the
6 mechanical components function in essentially the
7 same manner as those featured in Fig. 2 and shall
8 only be described by exception. The principal
9 differences are the configurations of the tubular
10 and sealing elements. The size of the pump is
11 limited by the internal diameter of the outer
12 tubular within which the pump assembly and its
13 associated tubulars and seals must be run and set. A
14 pump assembly attached at its upper end to a tieback
15 tubing string 109 is installed within a cemented
16 casing string 105, the tieback tubing string being
17 hung at the wellhead. The lower end of the pump
18 assembly has chevron seal elements 160 carried on a
19 spacer string 161, the length of the spacer string
20 being determined by operational requirements. For
21 brevity, spacer string 161 is shown as a single
22 item. The chevron seals set the polished-bore
23 receptacle 108 which is sited at the top of the
24 liner - not shown but corresponds to item 7 of Fig.
25 1. An alternative method of achieving the lower seal
26 for the pump is to use a packer to replace the PBR.
27 Tubular 111b, which is attached to the inner
28 connection of lower body 170 of the pump, extends to
29 an inner PBR - not shown but corresponds to item 15
30 of Fig. 1. After the pump assembly has been
31 installed in the well, tubing 111a is run from the
32 wellhead and attached the pump assembly's upper,

1 inner connection by a lock/seal system of which many
2 are available within the industry. It is seen on
3 Fig. 3 that the flow system is essentially the same
4 as that of Figs 1 and 2 but the size of the pump,
5 where the same tubular program is used on all
6 embodiments, is significantly increased owing to the
7 limiting size being that of the casing 5 or 105 as
8 referred to in Figs 1 and 3 respectively.

9

10

11 From this present embodiment it will be evident that
12 modifications could be made to the basic system
13 which enhance its installation and operation under
14 various circumstances. Due to the flow coupling
15 having a possible castellated mating form to the
16 pump shaft 34 then the turbine unit could be
17 separately installable/retrievable/replaceable by
18 wireline or coiled tubing to suit the pump duty as
19 downhole conditions vary with time.

20

21 Tubular goods sizes for drilling and completion of
22 oil wells vary for different geographical locations
23 and it should be noted that any sizes shown or cited
24 herein are typically used in the North Sea and
25 should not be construed in any limiting sense.

26

27 The assemblies of Figs. 1 to 3 can be located at any
28 desired depth in the well within casing string 5
29 which determines the maximum pump diameter. These
30 embodiments provide an outer annulus for recovery of
31 produced fluids and an inner bore for injection of a
32 drive fluid to power the turbines and also for

1 injection of fluid into the aquifer to increase
2 recovery of produced fluids from the payzone of a
3 formation. The drive fluid exhausts through the pump
4 into a targeted injection zone within the aquifer.

5
6 It is also possible that very high pressure fluids
7 from a deep-set abnormally pressured reservoir would
8 provide the drive fluid to a turbine thus providing
9 power to a pump to drive a pump for a lower pressure
10 reservoir sited some distance above the former.
11 This system would act as a pressure exchanger with
12 both fluids being produced to surface.

13
14 Seals, although depicted and described as chevron
15 types, can be of any desired type typically employed
16 in the industry.

17
18 It should be noted that for clarity no details of
19 shaft bearings have been shown in the drawings.
20 However, pump shaft design and bearings therefor are
21 well established and known to those in the art.

22
23 It is an especially preferred embodiment of the
24 invention to provide a seal system such as a packer
25 on a portion of the inner string so as to facilitate
26 the sealing of the inner string or a chosen location
27 within the outer string.

28
29 In certain cases, the origin of the produced fluids
30 may be multilateral branches drilled through and out
31 of the main well bore rather than perforations in
32 the tie back tubing.

1
2
3 It is anticipated that for fractured or segmented
4 reservoirs and aquifers, the injected and produced
5 fluids would not necessarily enter into or originate
6 from the aquifer and reservoir of a given oil-water
7 contact. Geological factors could dictate that the
8 injection fluid would preferably target the aquifer
9 beneath a neighbouring reservoir separated from that
10 of the well by an isolating fracture.

11

12

1 CLAIMS

2

- 3 1. A method and apparatus for enhanced, combined
4 hydrocarbon production and water injection
5 operations in a single well wherein the method
6 comprises:
7 pumping injection water down the well to drive a
8 hydraulic turbine unit within a downhole pump
9 assembly;
10 utilising the pump unit to increase the
11 production rate of hydrocarbons from the well;
12 ensuring passage of the injection water directly
13 through the pump unit on exhausting from the
14 turbine en route to the injection zone;
- 15 2. The apparatus of claim 1 comprising:
16 an inner tubing string running from the tubing
17 hanger set in the Christmas tree at the wellhead
18 to the downhole liner;
19 an outer tubing string running from the tubing
20 hanger set in the Christmas tree at the wellhead
21 to the downhole liner;
22 a pump assembly provided by appropriate threaded
23 connections as part of the inner tubing string.
- 24 3. The pump assembly of claims 1 and 2
25 characterised, in combination, by:
26 a packoff and slips module;
27 a hydraulic rotary turbine mounted on and
28 assembled to a solid shaft;
29 a hydraulic rotary pump of which the constituent
30 impeller stages are mounted on and assembled to a
31 hollow shaft;

- 1 a flow coupling linking the solid shaft of the
- 2 turbine to the hollow shaft of the pump;
- 3 a check valve set in the assembly above the
- 4 turbine unit.
- 5 4. The flow coupling of claim 3 which provides a
- 6 mechanical link from the solid shaft of the
- 7 turbine unit to the hollow shaft of the pump unit
- 8 and further permits passage of the fluid
- 9 exhausting from the turbine unit through to said
- 10 hollow shaft of the pump unit.
- 11 5. The hollow shaft of any preceding claims to which
- 12 the impeller elements of the pump are fixed and
- 13 through which shaft the injection fluid passes to
- 14 the attached injection tubing.
- 15 6. The packoff and slips module of claim 3 which
- 16 seals and locks against the bore of the outer
- 17 tubing string.
- 18 7. The inner tubing string of claim 2 which runs
- 19 from a tubing hanger at the wellhead to an
- 20 injection packer set within the downhole liner at
- 21 a position below the production flow entry
- 22 point(s) to the well, and of which tubing string
- 23 the pump assembly is an element set at a depth
- 24 appropriate to reservoir performance
- 25 characteristics.
- 26 8. The method of any preceding claims whereby
- 27 hydrocarbons emanating from the production zone
- 28 of the well and thus being present in the lower
- 29 annulus formed by the inner and outer tubing
- 30 strings enter the pump unit at the local pressure
- 31 and pass through the impeller stages to be
- 32 discharged from the pump unit at an elevated

1 pressure into the upper annulus with the packoff
2 ensuring separation of the high and low pressure
3 fluids across the pump.
4 9. The apparatus of claim 2 wherein the pump
5 assembly is provided as part of the outer tubing
6 string.
7 10. The apparatus of claims 2 and 9 wherein the lower
8 inner tubing string runs from the pump assembly
9 to the injection packer.
10 11. The apparatus of claims 2, 9 and 10 wherein the
11 upper inner tubing string is a separate item run
12 from the wellhead to the pump assembly subsequent
13 to the installation downhole of the outer tubing
14 string of claim 9.
15
16
17
18

Amendments to the claims have been filed as follows

1. A method for enhanced, combined hydrocarbon production and water injection operations in a single well wherein the method comprises:
 - pumping injection water down the well to drive a hydraulic turbine unit within a downhole pump assembly;
 - utilising the pump unit to increase the production rate of hydrocarbons from the well;
 - ensuring passage of the injection water directly through the pump unit on exhausting from the turbine en route to the injection zone;
2. An apparatus to ensure the good operation of the method of claim 1 comprising:
 - an inner tubing string running from the tubing hanger set in the Christmas tree at the wellhead to the downhole liner;
 - an outer tubing string running from the tubing hanger set in the Christmas tree at the wellhead to the downhole liner;
 - a pump assembly provided by appropriate threaded connections as part of the inner tubing string.
3. The pump assembly of claim 2 further characterised, in combination, by:
 - a packoff and slips module;
 - a hydraulic rotary turbine mounted on and assembled to a solid shaft;
 - a hydraulic rotary pump of which the constituent impeller stages are mounted on and assembled to a hollow shaft;

- 1 a flow coupling linking the solid shaft of the
2 turbine to the hollow shaft of the pump;
3 a check valve set in the assembly above the
4 turbine unit.
- 5 4. The flow coupling of claim 3 which provides a
6 mechanical link from the solid shaft of the
7 turbine unit to the hollow shaft of the pump unit
8 and further permits passage of the fluid
9 exhausting from the turbine unit through to said
10 hollow shaft of the pump unit.
- 11 5. The hollow shaft of any preceding claims to which
12 the impeller elements of the pump are fixed and
13 through which shaft the injection fluid passes to
14 the attached injection tubing.
- 15 6. The packoff and slips module of claim 3 which
16 seals and locks against the bore of the outer
17 tubing string.
- 18 7. The inner tubing string of claim 2 which runs
19 from a tubing hanger at the wellhead to an
20 injection packer set within the downhole liner at
21 a position below the production flow entry
22 point(s) to the well, and of which tubing string
23 the pump assembly is an element set at a depth
24 appropriate to reservoir performance
25 characteristics.
- 26 8. The method of any preceding claims whereby
27 hydrocarbons emanating from the production zone
28 of the well and thus being present in the lower
29 annulus formed by the inner and outer tubing
30 strings enter the pump unit at the local pressure
31 and pass through the impeller stages to be
32 discharged from the pump unit at an elevated

- 1 pressure into the upper annulus with the packoff
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- 4 9. The apparatus of claim 2 wherein the pump
5 assembly is provided as part of the outer tubing
6 string.
- 7 10. The apparatus of claims 2 and 9 wherein the lower
8 inner tubing string runs from the pump assembly
9 to the injection packer.
- 10 11. The apparatus of claims 2, 9 and 10 wherein the
11 upper inner tubing string is a separate item run
12 from the wellhead to the pump assembly subsequent
13 to the installation downhole of the outer tubing
14 string of claim 9.
- 15
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Claims searched: 1-11

Examiner: Dr. Lyndon Ellis
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Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.T): E1F FLM, FMU

Int CI (Ed.7): E21B

Other: Online: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X, P	GB 2358202 A (Mentor) Whole document, noting fig 2 and page 3, lines 21 to page 4, line 19	1 at least
X	GB 2324108 A (Weir) Whole document	1-11
A	US 6056054 (Atlantic)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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